Modeling Regional Trends in Waste Production Across the Philippines Using ARIMA

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DOI: https://doi.org/10.56293/IJASR.2024.6207

IJASR 2024
VOLUME 7
ISSUE 6 NOVEMBER – DECEMBER **ISSN: 2581-7876**

Abstract: Waste generation has emerged as a critical global environmental concern, exacerbated by population growth, urbanization, and rising consumption patterns. In the Philippines, as one of Southeast Asia's top waste output contributors, inadequate waste management practices, low recycling rates, and inefficiencies in local waste collection systems have intensified pollution challenges, particularly in coastal areas. This study addresses the country's waste management challenges by forecasting regional waste generation trends using the ARIMA (Auto Regressive Integrated Moving Average) model. ARIMA's time series forecasting capability enables the prediction of future waste quantities based on historical data, providing local government units with insights essential for capacity planning and policy interventions. The ARIMA model forecasted waste generation trends of the region in the Philippines for the next decade, using historical data from 2014 to 2023. The forecast of waste generation of each region reveals three main patterns. The first is a decline following an initial rise in 2024, the second is a steady downtrend starting in 2024, and lastly, an upward trend after a dip in 2024. These patterns suggest regional differences in waste output and inform the government about more targeted waste management strategies, such as conducting policies and regulations. NCR, Region 2, Region 3, and Region 13 are projected to see a temporary rise followed by a gradual decline hinting at a stabilization. Regions 1, 4, MIMAROPA, and Regions 5–12 show a consistent decline starting in 2024, likely reflecting sustained waste reduction. CAR, however, displays a unique upward trend after 2024, indicating factors that may drive increased waste generation. Among all the regions, only BARMM has insufficient data, which is why forecasting in this region is not possible. Further research could address this gap if additional PSA data becomes available.

Keywords: ARIMA, waste generation, waste management, forecasting, time series

1. Introduction

Waste generation in our environment is a major global issue that has received much attention. Waste is a residue or material that no longer has a use or purpose and needs to be disposed of. According to the United States Environmental Protection Agency (US Environmental Protection Agency, 2024), it is stated that there are various types of generated waste, namely municipal waste, industrial waste, non-hazardous waste, hazardous waste, agricultural and animal waste, medical waste, radioactive waste, construction debris, mining waste, gas and oil production waste, fossil fuel combustion waste, and sewage sludge. Due to the increasing population and economic development, a region's consumption habits and waste generation have increased significantly, resulting in severe issues for public health and the environment (Sharma & Jain, 2020). The UN Environment Programme (UNEP) stated that by 2050, waste generation is predicted to increase to 3.8 billion tons, increasing significantly from the current 2.1 billion tons (UN Environment Programme, 2024). Due to commercial product production's prevalence, people are becoming more consummative, and the necessities of human lifestyles are becoming more diverse. This consummative manner will degrade the quality of the environment by exploiting natural resources (Azizah & Aji, 2024).

Waste generation is one of the common problems in most developing countries, especially in Asia. The Philippines is one of the top waste generators in Southeast Asia and among the top countries contributing to plastic waste pollution in the seas. This is due to low recycling rates, issues of garbage collection implementation, and plastic package segregation consistency in many local government units (LGU). The Philippines is recognized as one of the best country destinations for tourism in Asia, featuring island beaches, historical sites, abundant nature, and diverse fauna that attracts tourism potential. Waste generation problems are prevalent along with the growing population, consumption growth, and expanding urbanization. The World Wildlife Fund reported that the Philippines consumes approximately 20 kilograms of plastic packaging annually, and 15.43 kilograms result in waste (World Wildlife Fund, 2020).

Waste generation problems must be handled properly because insufficient waste collection may lead to environmental vulnerability, pollute the ecosystem, and cause flooding, especially in coastal areas. Moreover, improper waste systems remain prevalent in the Philippines, as open and controlled dumpsites are still operating. The issue poses significant risks to human health, destruction of land and marine life, and impedes economic development (Yoshioka et al., 2021). In this study, an analysis related to the projection of waste generation in all regions of the Philippines is significant. Thus, the amount of waste generated in the future will be projected to help the local government unit (LGU) immediately respond to the issues of waste generation in the Philippine regions (Coracero et al., 2021).

Forecasting is estimating the sequence of events that will happen over a long period. The most popular forecasting production is Time Series Forecasting (TSF), which gives a sequence of results of predicted future data outputs from quantitative modeling models (Khan & Alghulaiakh, 2020). The method used in this study for forecasting is the ARIMA model. The ARIMA (Auto Regressive Integrated Moving Average) model forecasts temporal dependencies using historical values and does not ignore the time series data (Azizah et al., 2024; Albeladi et al., 2024; Talirongan et al., 2021). Data-driven analysis, whether from a trend behavioral or regional perspective, has helped different fields. For instance, (Saren et al., 2021) expressed various clustering techniques that can be used when analyzing patterns in students' behavior. Similarly, our study employs the ARIMA model to project waste generation trends of the regions in the Philippines. The ARIMA model forecasts of waste generation help identify distinct patterns and inform waste management strategies to the authorities.

2. Review of Related Literature

2.1 Waste Management Processes

Waste management efficiency refers to various processes involving collection, sorting, and recycling processes vital in waste control. Multiple studies incorporating the ARIMA forecasting model have given a clear overview of how these models can predict future waste patterns; this information is meant to assist waste management facilities in arriving at an effective strategy plan for their capacity building. For instance, (Sriploy & Lertpocasombut, 2020) applied ARIMA to predict the volume of municipal solid waste about waste management. Their research showed that an accurate forecast of waste amounts yields extended assistance planning in disposal, capacity building, and storage area expansions to avoid overflows and ensure effective waste management. A similar study by (Zafra-Mejía, 2021) used the ARIMA models to forecast sessional rubbish fluctuations, including rate changes across monthly and yearly periods. The forecast enables the waste management centers to handle the expected levels of waste, making them more efficient. The ARIMA forecasting is also helpful during the recycling and sorting of waste. In the study of Liotiris & Andreopoulou (2022), ARIMA was used in waste generation composition forecasting and thus streamlined sorting facilities against anticipated recyclable volumes. Their research underlines how the outputs for ARIMA predictions are effective in laying the ground for effective operations in waste management.

2.2 Policies and Regulation

Various studies have identified how government policies and regulations are one of the main contributing factors in waste generation and management. Most of the research has utilized an ARIMA forecasting method in analyzing the impact of the waste policies on the rate of generation, hence allowing the policy actors to identify the trends in what is being produced for the view of predicting the effectiveness of regulatory action in time. A study by Bagwan (2024) uses the ARIMA model to assess the impact of enforced waste management policies. Their study resulted in a decrease in the generation of waste, especially electronic waste and e-waste, in regions where the policies are in force, thereby confirming that ARIMA is right in projecting good results for effective interventions in waste reduction. Similarly, Liotiris et al. (2022) and Addae et al. (2023) have used the ARIMA to project waste generation under several policy implementations, including strict recycling ordinances and landfilling restrictions. Their research showed that policies congruent with sustainable development goals had the potential, among other things, to diminish waste generation in the future.

2.3 Behavioral and Socioeconomic Factors

Research has also proven that behavioral and socioeconomic factors are critical determinants of waste generation. Using the ARIMA model, results have proven valuable in forecasting the influences of the mentioned factors. An example is the study conducted by Adewuyi et al. (2024), where they found that the populations with higher income status generated more waste by projecting trends using ARIMA models. This proposes that socioeconomic growth could significantly lead to a waste generation increase, which leads to higher disposal demands. Behavioral patterns also play a role in molding waste trends. A study by Azizah & Aji (2024) examined the consumptive lifestyle and its impact on waste generation, using the ARIMA to determine the changes as driven by consumer behaviors. Their study showed that areas with higher consumers had found a consistent increase in waste generation, while regions with efficient waste management practices saw reductions, supporting the behavior-focused intervention strategic planning

3. Methodology

3.1 Materials

This study uses population data from censuses carried out in 2010, 2015, and 2020 by the Philippine Statistics Authority (PSA). These censuses are essential sources of demographic information because they enable the study of waste generation trends in regions of the Philippines. It's worth noting, however, that BARMM only has available data from 2023, which limits the ability to forecast waste trends for this area. Data sources include the Environmental Management Bureau and the Department of Environment and Natural Resources. The data covers the period from 2014 to 2023. Several regions were presented in the statistics. Still, this study will only focus on the environmental data relating to the waste generation measured in tons in the areas of the Philippines.

3.2 Methods

The study made use of the Autoregressive Integrated Moving Average (ARIMA) model, a Python-based program employed for the analysis of time series, which is ideal for data in a sequential form. ARIMA primarily operates on time-based data patterns and, thus, allows for highly accurate time series prediction, even with a minimal size of the data sample (Roy et al., 2021; Ilie et al., 2020). In this study, the ARIMA (p, d, q) configuration was used to predict future waste generation trends across various regions in the Philippines over the next ten years. ARIMA (p, d, q) model is defined as follows:

$$Xt = \Phi 1\, X_{t-1} + \ldots + \Phi_p X_{t-p} + a_t - \Theta_1\, a_{t-1} - \ldots - \Theta_q a_{t-q} \quad (1)$$

Where the Φ's (phis) represent the autoregressive parameters to be estimated, while the Θ's (thetas) correspond to the moving average parameters to be determined, the original series is denoted by X's, and A's denotes unknown random errors, which are assumed to follow a normal probability distribution.

The study followed three key steps to predict waste generation in each region using ARIMA-related modules. First, model identification involves applying autocorrelation and partial autocorrelation analyses to detect random, stationary, and seasonal effects in the time series data. The researcher prepared a stationary time series by taking the differences and then selected the models on the premise of an autocorrelogram and a partial autocorrelogram. Parameter estimation and model testing were conducted to compare these models, ultimately choosing the most suitable one. Predictive analysis was then performed using GRETL (Gnu Regression, Econometrics, and Time-series Library) software for data visualization and analysis. Figure 1 illustrates the architectural framework for forecasting waste generation incidences in each region.

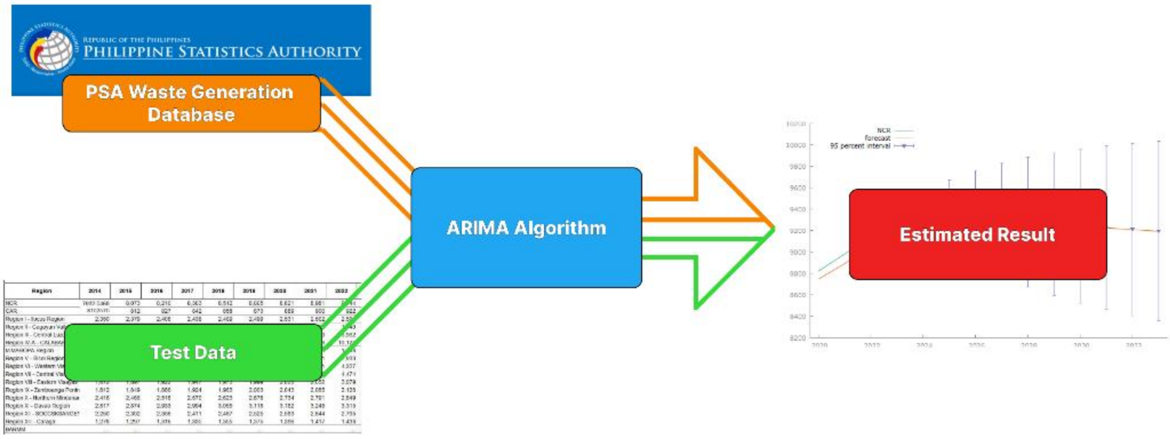

Figure 1. Predicting waste generation trends.

4. Results and Discussion

The GRETL software was utilized to analyze the trend of waste generation in various regions in the Philippines. This analysis is essential for understanding the evolution of waste production over time and at the same time, it helps spot patterns that could guide future attempts in tackling waste generation. Table 1 presents the raw data of waste generation which covers the years from 2014 to 2023.

Table 1. Raw data of waste generation by region

Projected Waste Generation in Tons	**Year**									
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
NCR	7932.55	8072.92	8216.29	8362.72	8512.29	8665.07	8821.15	8980.60	9143.51	9290
CAR	797.74	812.26	827.07	842.16	857.54	873.23	889.22	905.53	922.16	862
Region I - Ilocos Region	2349.57	2378.80	2408.40	2438.38	2468.73	2499.47	2530.59	2562.10	2594.01	2584
Region II - Cagayan Valley	1557.45	1579.19	1601.23	1623.58	1646.25	1669.24	1692.55	1716.20	1740.17	1762
Region III - Central Luzon	5863.05	5989.87	6119.55	6252.16	6387.76	6526.42	6668.29	6813.26	6961.52	7095
Region IV-A - CALABARZON	7854.08	8105.40	8365.36	8634.27	8912.46	9200.26	9498.02	9806.10	10124.87	9725
MIMAROPA Region	1374.54	1401.41	1428.90	1457.03	1485.82	1515.27	1545.42	1576.26	1607.83	1614
Region V - Bicol Region	2613.03	2651.06	2689.65	2728.81	2768.54	2808.87	2849.79	2891.32	2933.46	2869
Region VI - Western Visayas	3796.88	3848.09	3900.02	3952.68	4006.07	4060.20	4115.09	4170.74	4227.18	4165
Region VII - Central Visayas	3824.74	3899.26	3975.57	4053.73	4133.81	4215.85	4299.93	4386.10	4474.44	4481
Region VIII - Eastern Visayas	1872.44	1896.99	1921.87	1947.11	1972.70	1998.64	2024.96	2051.64	2078.69	2017
Region IX - Zamboanga Peninsula	1812.40	1848.78	1885.98	1924.03	1962.94	2002.74	2043.45	2085.10	2127.70	2033

Region X - Northern Mindanao	2416.22	2466.34	2517.55	2569.87	2623.33	2677.96	2733.78	2790.81	2849.10	2726
Region XI - Davao Region	2816.77	2874.49	2933.46	2993.69	3055.21	3118.05	3182.24	3247.81	3314.80	3224
Region XII - SOCCSKSARGEN	2250.10	2302.47	2356.05	2410.92	2467.09	2524.60	2583.47	2643.74	2705.45	2582
Region XIII - Caraga	1277.67	1296.65	1315.90	1335.44	1355.27	1375.41	1395.84	1416.60	1437.66	1467
BARMM	…	…	…	..	…	…	…	…	…	2144

4.1 Forecasting

The ARIMA model was used to forecast waste generation trends in the Philippines' regions for the next ten years, utilizing the available historical data from 2014 to 2023. The forecast results reveal three distinct patterns which are a downward trend after an initial increase in 2024, a steady downward trend beginning in 2024, and an upward trend following a dip in 2024. These patterns highlight shifts in waste generation levels over time as projected by the ARIMA model and provide insights into expected regional trajectories.

In the regions NCR, Region 2, Region 3, and Region 13, the predicted figures show a decreasing trend after a climb in 2024. This pattern suggests a temporary rise in waste generation that possibly reflects recent historical increases but is expected to be followed by a decline in subsequent years. This decline in projected waste generation can be an indication of either stabilization or correction. Therefore, the reasons behind the earlier surge are likely to diminish. Figures 3 to 6 display the predicted trends for each of the designated regions.

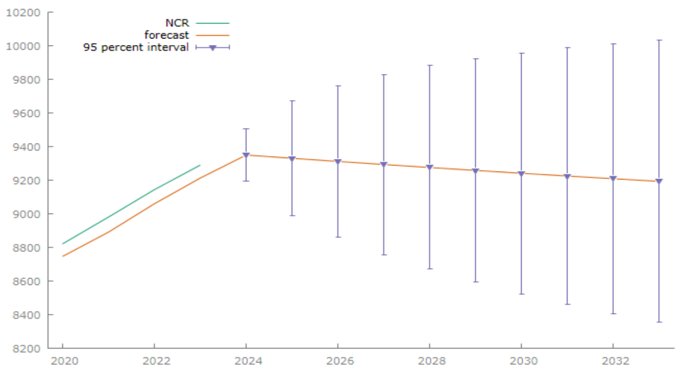

Figure 3. Forecasted waste generation of NCR

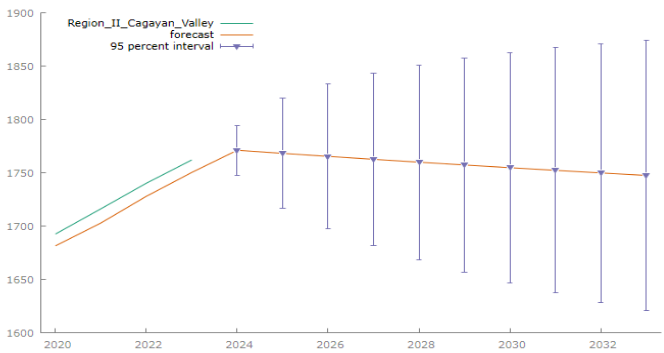

Figure 4. Forecasted waste generation of Region II

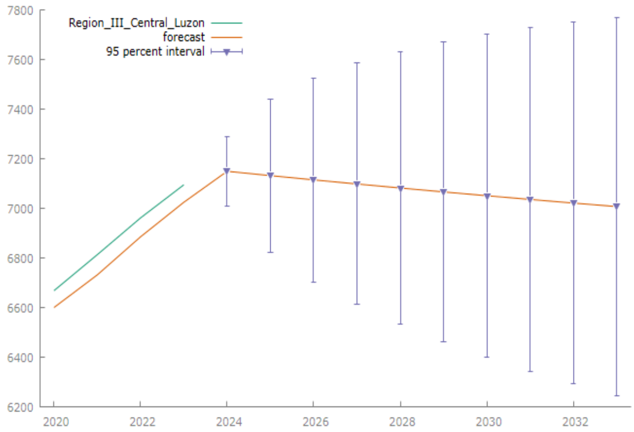

Figure 5. Forecasted waste generation of Region III

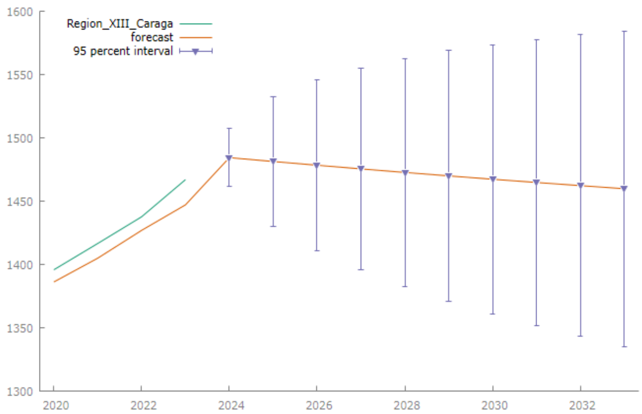

Figure 6. Forecasted waste generation of Region XIII

In contrast, regions such as Region 1, Region 4, MIMAROPA, and Regions 5 through 12 exhibit a steady downward trend beginning in 2024. The consistent waste reduction in these regions indicates that the factors responsible for waste generation might reduce their influence over time. This trend suggests that a long-term reduction in waste generation is anticipated. Figures 7 through 17 display the forecasted trends of the regions in this pattern.

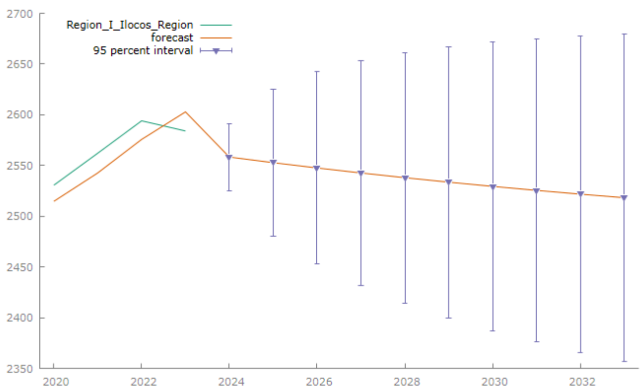

Figure 7. Forecasted waste generation of Region I

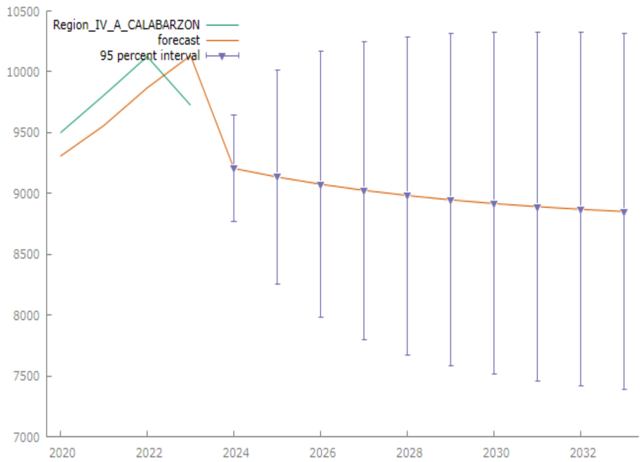

Figure 8. Forecasted waste generation of Region IV

Figure 9. Forecasted waste generation of MIMAROPA

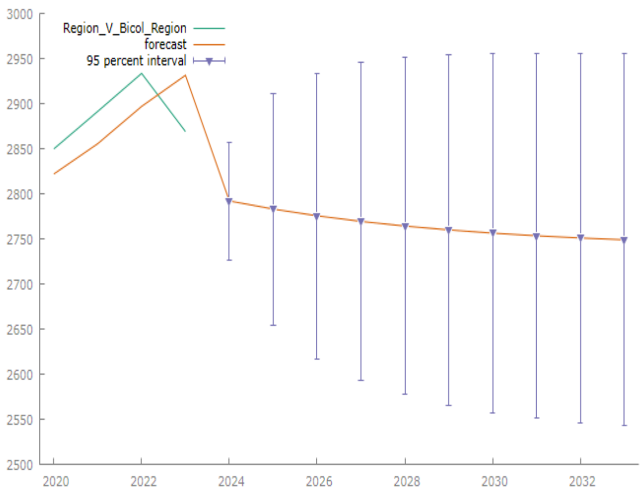

Figure 10. Forecasted waste generation of Region V

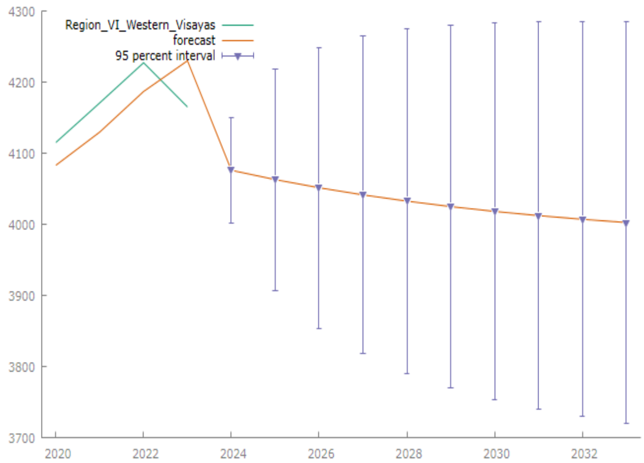

Figure 11. Forecasted waste generation of Region VI

Figure 12. Forecasted waste generation of Region VII

Figure 13. Forecasted waste generation of Region VII

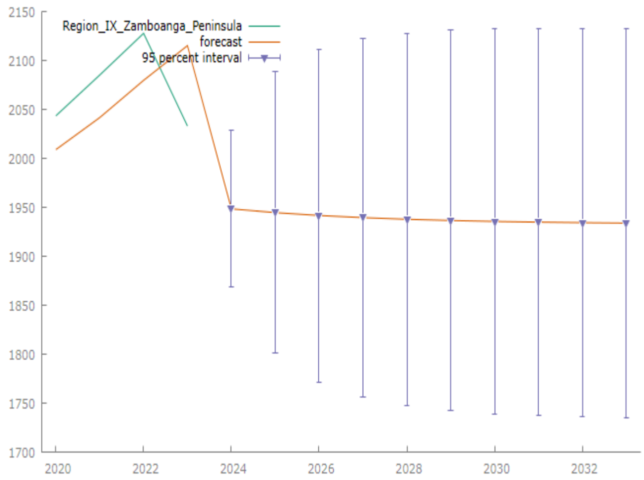

Figure 14. Forecasted waste generation of Region IX

Figure 15. Forecasted waste generation of Region X

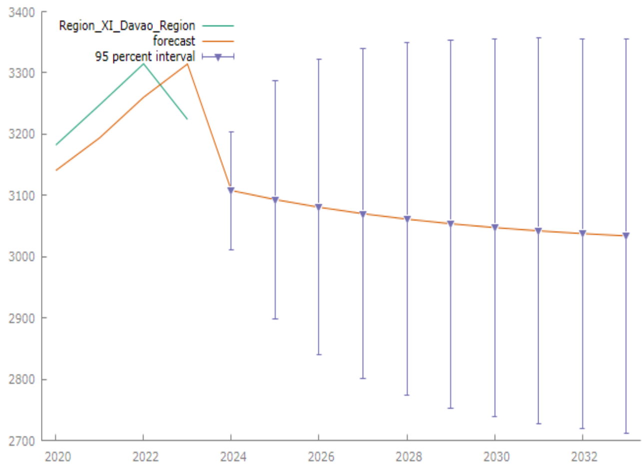

Figure 16. Forecasted waste generation of Region XI

Figure 17. Forecasted waste generation of Region XII

The forecast for CAR is unique among the rest because it shows an upward trend that will start after a minor decline in 2024. Although this initial dip may reflect temporary variations in waste generation, the anticipated rise in 2025 and subsequent years implies that CAR has fundamental factors that contribute to a continued increase in waste output. Figure 18 illustrates the forecasted trend for CAR.

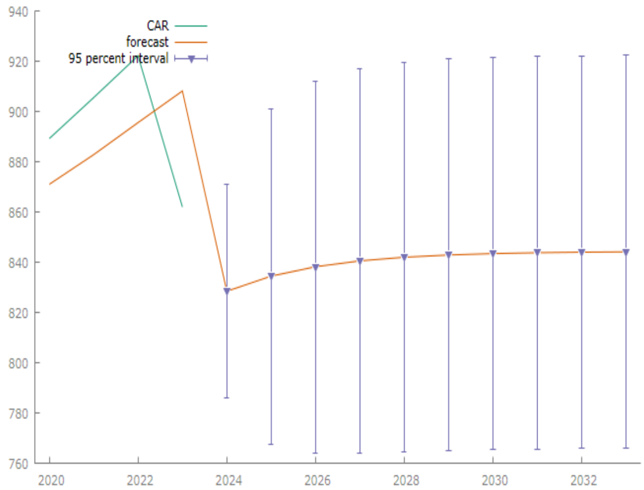

Figure 18. Forecasted waste generation of CAR

5. Conclusion and Recommendations

The ARIMA model analysis provided insights into waste generation trends across the regions in the Philippines for the next decade based on historical data from 2014 to 2023. The forecast of waste generation of each region displays three main patterns. The first is a decline after the initial rise in 2024, the second is a steady downtrend starting in 2024, and lastly, an upward trend after a fall in 2024. The existing patterns indicate the regional differences in waste output, therefore elaborating on a more realistic approach to implementing waste management, such as conducting effective policies, programs, legislation, and regulations. Notably, NCR, Region 2, Region 3, and Region 13 display a projected temporary increase in waste generation followed by a gradual decline, which possibly suggests a probable stabilization or correction in waste output levels. Conversely, Region 1, Region 4, MIMAROPA, and Regions 5 to 12 show a consistent decline beginning in 2024, which possibly may imply sustained reductions in waste production. The CAR region stands out, however, with an upward trend anticipated after 2024, indicating unique factors that may drive waste generation in this area over time.

The analysis highlighted data limitations in BARMM, where forecasts could not be made due to limited historical data. Future research can aim to generate forecasts for this region if additional annual data from PSA becomes available, allowing for more comprehensive ARIMA modeling and uniform insights across all regions in the Philippines. The analysis highlighted data limitations in BARMM, where forecasts could not be made due to limited historical data. Future research can aim to generate forecasts for this region if additional annual data from PSA becomes available, allowing for more comprehensive ARIMA modeling and uniform insights across all regions in the Philippines.

References

1. Addae, G., Oduro-Kwarteng, S., Fei-Baffoe, B., Rockson, M. A. D., Antwi, E., & Ribeiro, J. X. F. (2023). Patterns of waste collection: A time series model for market waste forecasting in the Kumasi Metropolis, Ghana. *Cleaner Waste Systems, 4*, 100086. https://doi.org/10.1016/j.clwas.2023.100086
2. Adewuyi, A. Y., Adebayo, K. B., Adebayo, D., Kalinzi, J. M., Ugiagbe, U. O., Ogunruku, O. O., & Richard, O. (2024). Application of big data analytics to forecast future waste trends and inform sustainable planning. *World Journal of Advanced Research and Reviews, 23*(1), 2469–2479. https://shorturl.at/FGdVOs
3. Albeladi, K., Zafar, B., & Mueen, A. (2023). Time series forecasting using LSTM and ARIMA. *International Journal of Advanced Computer Science and Applications, 14*(1), 313–320. https://tinyurl.com/d2xdb4mn
4. Azizah, R. N., & Aji, R. P. (2024). Prediction of waste generation in Yogyakarta Special Region Province using ARIMA model. *International Journal of Informatics and Information Systems, 7*(2), 63–75. https://www.ijiis.org/index.php/IJIIS/article/view/200/141
5. Bagwan, W. A. (2024). Electronic waste (E-waste) generation and management scenario of India, and ARIMA forecasting of E-waste processing capacity of Maharashtra state till 2030. *Waste Management Bulletin, 1*(4), 41–51. https://www.sciencedirect.com/science/article/pii/S294975072300024X?via%3Dihub2
6. Coracero, E. E., Gallego, R. J., Frago, K. J. M., & Gonzales, R. J. R. (2021). A long-standing problem: A review on the solid waste management in the Philippines. *Indonesian Journal of Social and Environmental Issues (IJSEI), 2*(3), 213–220. https://doi.org/10.47540/ijsei.v2i3.144
7. Ilie, O. D., Ciobica, A., & Doroftei, B. (2020). Testing the Accuracy of the ARIMA Models in Forecasting the Spreading of COVID-19 and the Associated Mortality Rate. *Medicina, 56*(11), 566. https://www.mdpi.com/1648-9144/56/11/566
8. Khan, S., & Alghulaiakh, H. (2020). ARIMA model for accurate time series stocks forecasting. *International Journal of Advanced Computer Science and Applications, 11*(7). https://doi.org/10.14569/ijacsa.2020.0110765
9. Liotiris, C., & Andreopoulou, Z. (2022). Forecasting landfilling indicators of municipal waste in Greece using univariate time-series model. *Agrárinformatika/Journal of Agricultural Informatics, 13*(1), 1–8. https://journal.magisz.org/index.php/jai/article/view/636/364
10. Philippine Statistics Authority. (n.d.). *Table 3.7.2: Projected waste generation by region, 2014 to 2023*. PSA. Retrieved October 24, 2024, from https://psa.gov.ph/
11. Roy, P., Ahmed, M. A., & Shah, M. H. (2021). Biogas generation from kitchen and vegetable waste in replacement of traditional method and its future forecasting by using ARIMA model. *Waste Disposal & Sustainable Energy, 3*(2), 165-175. https://link.springer.com/article/10.1007/s42768-021-00070-3
12. Saren, J. G., Talirongan, H., Talirongan, F. J. B., & Malicay, C. L. (2021). Mining student behavioral concern through referrals using k-means clustering. *Min. Student Behav. Concern Through Referrals Using K-Means Clustering, 71*(1), 19–19. https://shorturl.at/3IJrT
13. Sharma, K. D., & Jain, S. (2020). Municipal solid waste generation, composition, and management: The global scenario. *Social Responsibility Journal, 16*(6), 917–948. https://www.emerald.com/insight/content/doi/10.1108/SRJ-06-2019-0210/full/html
14. Sriploy, S., & Lertpocasombut, K. (2020). Industrial wastes to wastes disposal management by using Box Jenkins-ARIMA models and created applications: Case study of four waste transport and disposal service providers in Thailand. *EnvironmentAsia, 13*. https://www.tshe.org/ea/pdf/EA13(1)_12.pdf
15. Talirongan, F. J. B., Talirongan, H., & Orong, M. Y. (2021). Modeling national trends on health in the Philippines using ARIMA. *arXiv preprint, arXiv:2101.01392*. https://arxiv.org/pdf/2101.01392
16. UN Environment Programme. (2024). *Global Waste Management Outlook 2024*. https://www.unep.org/resources/global-waste-management-outlook-2024
17. United States Environmental Protection Agency. (2024). *Waste*. https://www.epa.gov/report-environment/wastes

18. World Wildlife Fund. (2020). *WWF continues to fight against plastic pollution, advocates for an extended producer responsibility scheme in the Philippines*. https://archive.wwf.org.ph/what-we-do/plastics/epr-launch/
19. Yoshioka, N., Era, M., & Sasaki, D. (2021). Towards integration of climate disaster risk and waste management: A case study of urban and rural coastal communities in the Philippines. *Sustainability, 13(*4), 1624. https://doi.org/10.3390/su13041624
20. Zafra-Mejía, C. A., Zuluaga-Astudillo, D. A., & Rondón-Quintana, H. A. (2021). Analysis of the landfill leachate treatment system using ARIMA models: A case study in a megacity. *Applied Sciences, 11*(15), 6988. https://doi.org/10.3390/app11156988

